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ABSTRACT

A meta-analysis was conducted of 29 comparative studies located primarily through computer searches of Comprehensive Dissertation Abstracts and ERIC. Studies chosen took place in actual elementary classrooms, reported measured outcomes for both computer-based education and control classes, and were free from methodological flaws. A total of 21 variables were used to describe aspects of the studies' experimental treatments, methodology, settings, and publication history. Outcomes were also coded, with student learning the most commonly measured outcome. Results showed that computer-based education has generally had positive effects on the achievement of elementary school pupils. These effects have been different, however, for programs of offline computer managed instruction (CMI) and for interactive computer assisted instruction (CAI). In 25 studies, CAI drill and practice and tutorial programs raised student achievement scores by 0.48 standard deviations (or from the 50th to the 68th percentile). In four studies, CMI programs raised student achievement scores by only 0.07 standard deviations. It is noted that study features were not significantly related to study outcomes. Forty-five references are listed. (LMM)

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Effects of Computer-based Education On Elementary School Pupils

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Abstract

A meta-analysis of 29 comparative studies showed that computer-based education has generally had positive effects on the achievement of elementary school pupils. These effects have been different, however, for programs of off-line computer-managed instruction (CMI) and for interactive computer-assisted instruction (CAI). In 25 studies, CAI programs of drill and practice and tutorial instruction raised student achievement scores by 0.48 standard deviations, or from the 50th to the 68th percentile. In 4 studies, CMI programs raised student achievement scores by only 0.07 standard deviations. Study features were not significantly related to study outcomes.

Effects of Computer-Based Education

On Elementary School Pupils

Using computers to teach children is a topic of great interest currently to parents, teachers, and researchers, but it is also is a hard topic to bring into focus. Even the terminology in the area is open to dispute. The acronym CAI is often used, but it is variously interpreted as standing for "computer-assisted instruction," "computer-aided instruction," "computer-augmented instruction," and "computer-administered instruction." Other terms used in the area are "computer-managed instruction," "computer-based learning," and "computer-based instruction." "Computer-based education," or CBE, is becoming increasingly popular as a generic term for the area because it encompasses a broad spectrum of computer applications (Hall, 1982).

The first uses of the computer in teaching occurred in the late 1950s at IBM's Watson Research Center (Levien, 1972). By 1958 researchers there had already programmed a digital computer to teach binary arithmetic. In 1960 IBM researchers announced the development of the first CBE language, Coursewriter, designed to enable educators to develop instructional modules without the aid of computer specialists. By 1961 IBM's system of CBE was being used for teaching stenotype, German, and statistics.

Major developments in CBE occurred at university research centers in the years that followed (Hall, 1982). In 1959 engineers, physicists, psychologists, and educators at the University of Illinois, under the leaderships of Donald Bitzer, began developing the CBE system that was to become known as PLATO (Programmed Logic for Automatic Teaching Operators). In 1963 Patrick Suppes and Richard Atkinson began research and development on CBE at the Institute of Mathematical Studies in the Social Sciences at Stanford University. In 1964 Pennsylvania State University established a CAI laboratory under the leadership of Harold E. Mitzel for research, development, and implementation in CBE.

The taxonomies used to describe the approaches developed at such centers usually distinguished between four uses of the computer (Atkinson, 1968; Watson, 1972).

1. Drill and Practice. The teacher presents lessons to pupils by conventional means, and the computer provides practice exercises as a follow-up to teacher presentations.

2. Tutorial. The computer both presents the concepts and provides practice exercises on the concepts.

3. Dialogue. The computer presents both lessons and practice exercises, and the student is free to construct natural language responses, ask questions in unrestricted mode, and almost completely control the sequence of learning events.

4. Computer-managed Instruction. The computer evaluates students either on-line or off-line, guides students to appropriate instructional resources, and keeps records.

The development of the microchip during the late 1960s and the invention of simplified programming languages greatly increased learner access to computers and broadened researcher conceptions about he role that computers can play in education. In recent years both Luehrmann (1980) and Papert (1980) have suggested that early conceptions of a computer-teacher were too limited. They believe that learners who program the computer to solve problems develop a better understanding of the problems. They argue therefore that for the maximum educational benefit children should teach computers, not be taught by them. The computer's true role in education, they claim, is to be a servant of children who program it, not the master of children it programs.

Recent taxonomies of CBE reflect these new ideas about computer uses. Taylor (1980), for example, describes three uses of the computer in schools:

1. Tutor. When functioning as a tutor, the computer presents subject material, evaluates student responses, determines what to present next, and keeps records records of student progress. Most computer uses described in earlier taxonomies involve the tutoring function of computers.

2. Tool. The computer serves as a tool when students use it for statistical analysis, calculation, or word processing. For example, the computer can serve as a calculator in mathematics classes, as a map-maker in geography, as a performer in music, or as a text editor and copyist in English.

3. Tutee. Students can tutor the computer by giving it directions in a programming language the computer understands, e.g., BASIC or LOGO. Learners are thought to gain new insight into their own thinking through learning to program.

Systematic comparisons of outcomes of computer-based and conventional teaching began appearing in print in the late 1960s. In a typical evaluation study, a researcher divided a group of students into an experimental and a control group. Members of the experimental group received

part of their instruction with computer assistance, whereas members of the control group received their instruction by conventional teaching methods. At the end of the experiment, the researcher compared responses of the two groups on a common achievement examination or on a course evaluation form.

Teachers and researchers carried out such studies in many settings during the past two decades. The studies varied in duration and in the number of students they involved. The studies were carried out with both commercial and locally designed materials. They were conducted as dissertation research, school-system evaluation projects, and university-sponsored studies. The evaluation designs of the studies included true randomized experiments and quasi-experiments.

Reviewers in recent years have tried to aggregate the results from the diverse evaluations in order to reach general conclusions about the effectiveness of CBE. Their reviews are of two basic types: box-score reviews and meta-analyses. Box-score reviews usually report the proportion of studies favorable and unfavorable to CBE, and often provide narrative comments about the studies as well. Reviewers using meta-analysis take a more quantitative approach to their task (Glass, McGaw, & Smith, 1981). They use (a) objective procedures to locate studies, (b) quantitative or quasi-quantitative techniques to describe study features and outcomes, and (c) statistical methods to summarize overall findings and explore relationships between study features and outcomes.

Reviewers using box-score methods concluded that CBE was effective in raising student achievement, especially in elementary schools. Vinsonhaler and Bass's review (1972), for example, reported that results from 10 independent studies showed substantial advantages for computer-augmented instruction. Elementary school children who received computer-supported drill and practice generally showed performance gains of 1 to 8 months over children who received only traditional instruction. According to Edwards, Norton, Taylor, Weiss, & Dusseldorp (1975) CBE often produced better results than did conventional teaching on end-of-course examinations. Findings were especially clear when CBE was used to supplement conventional teaching. Of the the nine relevant studies reviewed, all showed that normal instruction supplemented by CBE was more effective than was normal instruction alone. Edwards and his colleagues also noted that CBE reduced the time it took students to learn.

Hartley (1977), who was the first to apply meta-analysis to findings on CBE, focussed on mathematics teaching in elementary and secondary schools. She reported

that the average effect of CBE was to raise mathematics achievement by 0.41 standard deviations, or from the 50th to the 66th percentile. Hartley also noted that although correlations between study features and outcomes were not generally high, a few study features significantly affected study outcomes. She pointed out, for example, that elementary students fared better with CBE than did secondary students. Burns and Bozeman (1981), like Hartley, used meta-analysis to integrate findings on computer-assisted mathematics instruction in elementary and secondary schools. They found overall effect sizes of 0.45 for computer-based tutorial instruction and 0.34 for drill and practice. They found virtually no evidence of a relationship between experimental design features and study outcomes.

Meta-analyses by J. Kulik and his colleagues covered a wider range of subject matters and computer applications than did the earlier syntheses. J. Kulik, Bangert, and Williams (1983) analyzed 51 studies of CBE conducted in Grades 6 through 12. They found that CBE raised the examination scores of students by 0.32 standard deviations, and also had positive effects on student attitudes and on the amount of time needed for instruction. In addition, J. Kulik, Kulik, and Cohen (1980) used meta-analysis to examine applications of CBE in college classes. The effect of CBE in a typical class was to raise student achievement by approximately 0.25 standard deviations, or from the 50th to 60th percentile. Kulik and his colleagues also reported that CBE substantially reduced the amount of time needed for instruction at the college level.

J. Kulik (1981) reviewed evidence from his own quantitative syntheses of findings and from Hartley (1977). Restricting his review to mathematics education, Kulik pointed out that CBE raised mathematics achievement scores by approximately 0.4 standard deviations at the elementary level, 0.3 standard deviations at the high school level, and 0.1 standard deviations at the college level. He concluded that CBE effectiveness may be a function of instructional level. He suggest that at the lower levels of instruction, learners need the stimulation and guidance provided by a highly reactive teaching medium. At the upper levels of instruction a highly reactive instructional medium may not be so necessary.

Further reviews are necessary to evaluate fully the model described by Kulik. Meta-analyses of elementary school applications of CBE have been especially limited in scope. They have been restricted to mathematics teaching and to drill-and-practice and tutorial applications of the computer. In addition, meta-analyses at this level are rapidly growing outdated. The meta-analyses by Hartley (1977) and by Burns and Bozeman (1981) covered no CBE

studies published after 1978. Major changes have occurred in the use of computers in instruction during the years not covered in these meta-analyses.

The meta-analysis described in this article was designed to further explore the effectiveness of computer-based education in Grades 1 through 6. The article is meant to answer the sorts of questions commonly asked by research synthesists. How effective is computer-based teaching in general at the elementary school level? Is it especially effective for certain types of outcomes or certain types of students? Under which conditions does it appear to be most effective?

Method

The meta-analytic approach used in this review was similar to that described by Glass, McGaw, and Smith (1981). Their approach requires a reviewer (a) to locate studies of an issue through objective and replicable searches; (b) to code the studies for salient features; (c) to describe study outcomes on a common scale; and (d) to use statistical methods to relate study features to outcomes.

Data Sources

To find studies examining CBE effects on elementary school students, we carried out computer searches of two library data bases: (a) Comprehensive Dissertation Abstracts, and (b) ERIC, a data base on educational materials from the Educational Resources Information Center, consisting of the 2 files Research in Education and Current Index to Journals in Education. The empirical studies retrieved in these computer searches were the primary source of data for our analyses. A second source of data was a supplementary set of studies located by branching from bibliographies in the review articles retrieved in the computer searches.

These bibliographic searches yielded a total of 29 studies that met three criteria for adequacy. First, the studies had to take place in actual classrooms in Grades 1 through 6. Studies describing laboratory analogues of classroom teaching did not meet this guideline. Second, studies had to report measured outcomes in both CBE and control classes. Studies without control groups and studies with anecdotal reports of outcomes failed to meet this criterion. And third, the studies had to be free from such crippling methodological flaws as substantial aptitude differences in treatment and control groups, unfair "teaching" of the criterion test to one of the comparison groups, and differential rates of subject attrition from the groups being compared.

Study Features

A total of 21 variables were used to describe aspects of the experimental treatments used in the studies, study methodology, study settings, and publication history (Table 1). The variables were selected for this analysis on two grounds: (a) a review of variables used to describe study features in our previous meta-analyses, and (b) a preliminary examination of dimensions of variation in the studies located for this analysis. Three coders independently coded each of the studies on each of the variables. The coders jointly reviewed their coding forms and discussed any disagreements in their coding of the studies. These disagreements were resolved through further examination of the studies and discussion.

Insert Table 1 about here

Outcome Measures

The instructional outcome measured most often in the 29 studies was student learning, as indicated on achievement examinations given at the end of a program or on follow-up examinations given some time after the completion of the program. Other outcome measures included in the studies tapped noncognitive educational gains, including changes in student attitudes towards their school subjects and toward computers. Although analyses were done separately for each type of outcome, common procedures were used in coding the outcomes.

The goal in coding study outcomes was to overcome the difficulties caused by the variety of units in which studies reported a single type of outcome. Achievement effects, for example, were sometimes reported as gains in grade equivalent units, sometimes as raw-score changes, sometimes as percentile changes, and so on. Attitudinal effects were likewise reported in a number of different units. For statistical analysis of results, effects had to be transformed to a common scale.

The transformation used in this meta-analysis was the one recommended by Glass, McGaw, and Smith (1981). They coded each outcome as an Effect Size (ES), defined as the difference between the mean scores of two groups divided by the standard deviation of the control group. For studies that reported means and standard deviations for both experimental and control groups, ES was calculated directly from the measurements provided. For less fully reported studies, ES was calculated from statistics such as *t* and *F*.

The application of these formulas was straightforward in most cases. In some studies, however, several statistical measures were used to report results on a given outcome. For example, some investigators reported raw-score differences between groups as well as covariance-adjusted differences, and some reported differences on a post-measure as well as differences in pre-post gains. In such cases, we used as the numerator of ES the difference that gave the most accurate estimate of the true population effect. That meant using covariance-adjusted mean differences rather than raw-score differences, and differences in gains rather than differences on post-tests. In addition, some reports contained several measures of variation that might be considered for use as the denominator of ES. We used the measure that provided the best estimate of the population variation in the criterion variable.

Statistical Analysis

Researchers sometimes reported more than one finding for a given outcome area. Some of the multiple findings resulted from the use of more than one experimental or control group in a single study. Others resulted from the use of several subscales and subgroups in measuring a single outcome. Using several different ESs to represent results from one outcome area in one study seems inappropriate to us. The multiple ESs are not independent; they often come from a single group of subjects or overlapping subject groups, and in any case they represent the effects of a single program implemented in a single setting. To represent a single outcome by several ESs violates the assumption of independence necessary for many statistical tests and also gives undue weight to studies with multiple groups and multiple scales.

The procedure we adopted therefore was to calculate only one ES for each outcome area of each study. A single rule helped us to decide which ES best represented the study's findings. The rule was to use the ES size from the most methodologically sound comparison when comparisons differed in methodological adequacy:

1. When a study included both a conventionally taught control group and a no-treatment control group, results from the comparison with the conventionally taught group were coded for analysis. This procedure controlled for the possibly confounding effects of differential time-on-task.

2. When results from both a true experimental comparison and a quasi-experiment were available in the same study, results of the true experiment were coded.

3. When results from a long and short CBE implementation were available, results from the long implementation were used.

4. When transfer effects of CBE were measured in a study in addition to effects in the area of instruction, the direct effects were coded for the analysis.

In all other cases, our procedure was to use total score and total group results rather than subscore and subgroup results in calculating ES.

Statistical analyses were carried out separately for each outcome area. One study feature--control for historical effects--was dropped from the statistical analyses because of the lack of variation among studies in this feature. In all but one study, both the experimental and the control treatments were administered concurrently. Another study feature--type of computer interaction--was eliminated from the analyses because of its unacceptably high correlation with the variable indicating type of computer use. All studies of computer-managed instruction involved use of the computer for off-line processing; all but one of the studies of drill-and-practice and tutorial instruction involved mainframe computers with on-line interaction via terminals.

Results

Twenty-five of the 29 studies used in this analysis reported results from computer-assisted instruction (CAI) programs, involving drill-and-practice or tutorial instruction. Only 4 studies reported results from computer-managed instruction (CMI). The two sets of studies differed strikingly in their study features. In the 25 CAI studies, for example, students used the computer interactively; in the 4 CMI studies, the computer processed student records off-line. But more important, preliminary examination of results showed that the CMI and CAI studies produced strikingly different results (Table 2). For this reason, results from CMI and CAI studies were analyzed separately.

Insert Table 2 about here

Computer-Managed Instruction

The achievement of the control students exceeded slightly the achievement of students taught with computer-management in two studies (Akkerhuis, 1974; Coffman and Olsen, 1980), but the difference between groups in these studies was trivial and non-significant. The achievement of CMI students was trivially higher than that of control

students in a study by Roberts (1982), but again the difference between groups was non-significant. In a study of CMI by Nabors (1974), however, the effect of CBE was positive and moderately high. The average ES in the four implementations, however, was 0.07. This average is clearly trivial in size.

The four studies provided little evidence for other positive effects of CMI. Only the study by Akkerhuis (1974) examined non-cognitive outcomes of instruction. In Akkerhuis's study the average ES on attitude toward subject was -0.20, and the average ES on attitude toward computers was -0.07. Both values are small or trivial in size, and neither can be considered statistically significant.

Computer-Assisted Instruction

The effects of CAI were clearly more positive than those of CMI. The clearest results were available on end-of-course achievement measures, but in other areas also results were basically positive.

Achievement Examinations. In each of 25 studies with results from achievement examinations, students from the CAI class received the better examination scores; in no study did students from the conventional class get better scores on a final examination on course content. A total of 20 of these 25 studies reported, in addition, that the difference between CAI and conventional classes was statistically significant. Overall, these box score results strongly favored CBE.

The index of effect size ES provides a more exact picture of the degree of benefit from CAI in the typical study. The average ES in the 25 studies was 0.48; the standard deviation of ES was 0.31; and its standard error was 0.063. The average ES for these CAI studies was significantly different from the average ES for CMI studies, $t(27) = 2.51$, $p < .02$.

The average ES of 0.48 for the CAI studies means that in the typical study, performance of CAI students was raised by 0.48 standard deviations. To interpret this effect more fully, it is useful to refer to areas of the standard normal curve. Approximately 68% of the area of this curve falls below a z-score of 0.48. We can conclude, therefore, that students from CAI classes performed at the 68th percentile on their examinations, whereas the students who received only conventional instruction performed at the 50th percentile on the same examinations. Or put in another way, 68% of the students from CAI classes outperformed the average student from the control classes.

Grade-equivalents provide another rough guideline for interpreting ESs. Glass et al. (1981) have discussed grade-equivalent units in the context of meta-analysis:

> By definition the average pupil will gain ten months of achievement in a school year, for example, the average third grade pupil will score 3.0 in early September and 4.0 by the end of the year. It is also known, as an empirical--not a definitional--fact that the standard deviation of most achievement tests in elementary school is 1.0 grade equivalent units; hence the effect size of one year's instruction at the elementary school level is about +1. (p. 103)

One can use this empirical relation between grade-equivalent scores and deviation-scores to estimate the approximate gain in grade equivalent units for CAI students. Their grade-equivalent scores would be nearly 5 months higher than the scores of comparable students taught by conventional teaching approaches.

Study features and achievement effects. Although the effect of CAI was moderate in the typical study, the size of effect varied from study to study. Effects of CAI ranged in size from a high of 1.3 standard deviations (Warner, 1979) to a low of 0.02 standard deviations (Easterling, 1982). It seemed possible that this variation in study outcome might be systematic, and we therefore carried further analyses to determine whether different types of studies were producing different results. These analyses, however, did not disclose any significant relationships between study features and final achievement scores (Tables 3 and 4).

Insert Tables 3 & 4 about here

Subgroup and subscore achievement effects. Several studies that were coded for overall achievement effects provided, in addition, information on scores of specific subgroups of students and on subtest scores as well as total test scores. Table 5 presents separate effect sizes for high and low ability students, primary and middle grade students, and scores on language and mathematics subtests in studies that reported more differentiated results.

Insert Table 5 about here

In each of the four studies that looked at effects separately for high and low aptitude students, the effects were greater on the low ability pupils. The average effect on the low ability students in the four studies was to

increase achievement test scores by 0.55 standard deviations; the average effect on the high ability students was to increase scores by 0.06 standard deviations. Grade level, however, did not appear to be consistently related to effect size in the six studies that examined results in both primary and middle grades. In two of the studies, effects were higher in the middle grades, and in four studies effects were larger in the primary grades. Finally, the three studies that reported language and mathematic results separately did not produce evidence for differential effects. In one study mathematics effects were greater than language effects; in another study, the language effect was greater than the math effect; and in the third study the two effects were approximately equal in size.

Follow-up examinations. Four of the CAI studies reported results from follow-up achievement examinations administered after the completion of computer-based and conventional teaching. In each of the studies, the follow-up scores were higher in the CAI class than in the conventional class. Delon (1970) reported a follow-up ES of 0.30; Dunn, Morgan, and Richardson (1974) an ES 0.47; Litman (1977) an ES of 0.08; and Prince (1969) an ES of 0.38. The average ES in the four studies was 0.31; the standard deviation of ES was 0.17, and the standard error was 0.10.

Attitudes toward subject. Only one of the CAI studies presented student attitude results in a fashion that yielded an ES (Cranford, 1976). That study showed a small and statistically nonsignificant positive effect of CBE on student attitudes towards mathematics. The ES in the study was 0.10.

Discussion

The major finding in this study was the positive effect that CAI had on achievement of elementary school children. In the typical application, students received approximately 26 hours of CAI --15 minutes per day, for 4 days a week, and for a total of 26 weeks. The effect of this instruction was to raise student achievement scores by 0.48 standard deviations, or from the 50th to the 68th percentile. A gain of this magnitude is roughly equal to a gain in grade-equivalent scores of 5 months.

This average effect is similar to average results reported in earlier reviews. Vinsonhaler and Bass (1972) reported an average increase of 4.5 months on a grade-equivalent scale from computer-based drill and practice in elementary school mathematics and language arts. Burns and Bozeman (1981) and Hartley (1977) reported gains of approximately 0.4 standard deviations from CAI in elementary school mathematics. Our meta-analysis showed that CAI is still producing such positive results.

This meta-analysis provides additional support for J. Kulik's (1981) model describing effects of instructional technology on school learning. The model suggests that CAI will be most effective at the elementary level of teaching, less effective at the secondary level, and least effective at the higher educational level. The deduction is based both on the characteristics of learners at different stages of development and on the characteristics of the computer that are exploited in CAI. According to the model, learners in the lower grades profit most from a highly structured and reactive teaching medium; college students have less need for highly structured learning materials, immediate feedback, and teacher control.

Kulik's model predicts that CMI will be less effective with young learners than CAI will be. This is because CMI exploits different features of the computer. In CMI, the computer simply acts as the teacher's clerk. It scores tests, keeps records, and arranges schedules. It may carry out all these duties off-line, and students in a computer-managed class may never see the computer. CMI is a form of individualized instruction, and like other systems of individualized instruction, it requires learners to pace themselves properly, work independently, and make their own choices. These requirements may exceed the abilities and motivation of very young learners. It is not surprising therefore that the greatest successes of computer-managed and individualized instruction have come at the higher grade levels (J. Kulik, Kulik, & Cohen, 1979; J. Kulik, Kulik, & Cohen, 1981; Bangert, Kulik, & Kulik, 1983).

Like other meta-analyses carried out in recent years, this one did not find strong relations between study features and outcomes. Studies with different features produced similar outcomes. ESs were very similar, for example, in true experiments and quasi-experiments. In ten other meta-analyses that our research team has carried out on effects of instructional technology, results from true- and quasi-experiments have been nearly identical (Bangert-Drowns, Kulik, & Kulik, 1984), and so we were not surprised by our failure to find differences on this study feature. Results with other study features, however, were less predictable. Bangert, Kulik, and Williams (1983) have suggested, for example, that CBE programs are growing more effective with time. In the present meta-analysis, ESs from different time periods were very similar. Other researchers have speculated that time-on-task might explain some of the variation in outcomes of computer-based teaching (e.g., Suppes & Morningstar, 1969). In this meta-analysis, ESs were very similar for implementations with and without controls for time-on-task.

Although not statistically significant, some study features tended to be related to CAI effect size. First, the average ES in published studies tended to be larger than the average ES in dissertations. This trend was also apparent in our ten other meta-analyses on instructional technology (Bangert-Drowns, Kulik, & Kulik, 1984), and the difference between ESs in dissertations and those in published articles can now be considered one of the best established findings in the literature of meta-analysis. Second, ES also seemed to vary with study scale. ESs tended to be larger when computer-based teaching was restricted to a single subject matter and smaller with multiple-course implementation. ESs also tended to be larger with short rather than long implementations. A negative relationship between study scale and ES often appeared in our ten previous meta-analyses on instructional technology. More work will be needed, however, to explain the underlying factors that contribute to this relationship.

It is also important to note that the computer's overall record of effectiveness rests on specific computers used in specific ways for specific purposes. The record may not apply to machines, approaches, and objectives not examined in the studies in our meta-analysis. Current interest in instructional computing, for example, has been stimulated greatly by the development of microcomputers in the last 15 years. Microcomputer-based systems have their own characteristics: their own software, their own management systems, and their own scale of operations. Only 1 of the 29 studies located for this meta-analysis examined the effects of a microcomputer-based system. Evaluators will have to give much more attention in the future to effects of such microcomputer-based systems. This meta-analysis may be helpful in future evaluations in that it provides standards by which effects can be measured.

As dramatic as changes in hardware have been in recent years, they are no more important than the changes that have occurred in conceptions of computer-based teaching. Early applications of the computer in teaching capitalized on the computer's tutoring capabilities. Computers presented lessons, gave learners drill and practice on course material, and kept student records. Recent development have broadened teacher conceptions of the role that computers can play in education. In addition to serving a tutorial function, computers are now used by students as learning tools and even as "tutees." Our computer searches produced no adequate evaluation studies of these exciting new developments in computer-based elementary-school teaching. Evaluation work on these areas is badly needed.

Evaluators also need to investigate a wider range of educational outcomes than they have in the past. They have repeatedly examined computer effects on achievement scores,

but they have given inadequate attention to pupil attitudes toward school, attitudes toward computers, and instructional efficiency. They have given almost no attention to higher order skills, transfer of gains to other areas, and interpersonal outcomes of computer uses in the classroom.

Educational evaluators are just now starting to turn their attention to such matters. It will take an enormous effort in the years ahead to produce a new set of up-to-date evaluation studies and to synthesize the findings from such studies. But judging by what has already been achieved, the effort may prove to be worthwhile. The years ahead promise to be exciting ones that may answer major questions about the best ways to use computers in teaching.

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Table 1

Categories Used to Describe Study Features

Use of computer

Drill and practice -- The computer provided practice exercises but not the original lesson on a topic.

Tutorial -- The computer presented the lesson as well as practice exercises on the material.

Management -- The computer evaluated student performance, guided students to appropriate instructional resources, and kept records of student progress.

Author of program

Local -- Computer materials were developed locally for a specific setting.

Other -- Computer materials were developed for use in a wide variety of settings.

CCC materials

Yes -- Materials used in the study were developed at Stanford University and were obtained from the Computer Curriculum Corporation of Palo Alto.

No -- Other materials.

Type of computer interaction

Off-line

Terminal with mainframe

Microcomputer

Number of CBE sessions per week

Total number of weeks of CBE

Number of minutes per CBE session

Total amount of time on CBE (in minutes)

Subject assignment

Random -- Subjects were randomly assigned to the experimental and control groups.

Nonrandom -- A quasi-experimental design was used.

Control for instructor effects

Same instructor -- The same teachers or teachers taught both the experimental and control groups.

Different instructors -- Different teachers taught the two groups.

Control for historical effect

Same semester -- Subjects in experimental and control groups were taught concurrently.

Different semester -- Two groups were not taught concurrently.

Control for time-on-task

Experimental > Control -- Experimental subjects received regular instruction plus supplemental computer assistance.

Experimental = Control -- Total amount of instructional time was equal for experimental and control groups.

Control for test-author bias

Commercial -- A standardized test was used as the criterion measure for student achievement.

Local -- A locally developed test was used as the criterion measure.

Control for bias in test scoring

Objective -- Objective, machine-scorable examinations were used to measure student achievement, e.g., multiple-choice tests.

Nonobjective -- Subjective decisions had to be made in scoring tests, e.g., essay tests.

Field-tested computer materials

Yes

No

Control for evaluator involvement

Involved -- The evaluator was involved in developing the CBE material and/or in conducting the CBE program.

Not involved

Class level

Primary -- Subjects included in the study came from Grades 1 through 3.

Primary and middle -- Subjects came from both primary and middle grades.

Middle -- Subjects came from Grades 4 through 6.

Course content

Mathematics

Science

Language Arts and/or Reading

Combined -- More than one of the above were studied.

Subject ability level

Low

Average or mixed

High

Source of study

Unpublished -- ERIC document, paper presented at a convention, etc.

Dissertation

Published -- Journal article, book, etc.

Year of the report

Table 2

Major Features and Achievement Effect Sizes in 29 Studies of Computer-Based Education

Study	Place & Time	Grade	Course Content	Use	Weeks of Instruction	Achievement ES
Akkerhuis (1974)	Germany, 1972-73	6	M	Management	18	-0.08
Atkinson (1967)	California, 1966-67	1	L	Tutorial	25	0.47[a]
Chiang, Stauffer & Cannara (1978)	California, 1977-78		C	D & P	35	0.19
Coffman & Olsen (1980)	Louisiana, 1976-78	3,4	C	Management	72	-0.01
Cranford (1976)	Mississippi, 1975-76	5,6	M	D & P	12	0.64
Davies (1972)	California, 1971	3-6	M	D & P	16	0.34
Delon (1970)	Mississippi, 1968-69	1	M	D & P	36	1.08
Dunn, Morgan & Richardson (1974)						
Study I	Maryland, 1972-73	4	M	D & P	11	0.45
Study II	Maryland, 1972-73	6	M	D & P	30	0.44
Durward (1973)	Canada, 1973	6,7	M	D & P	6	0.19
Easterling (1982)	Texas, 1982	5	C	D & P	16	0.02
Feifar (1969)	Indiana, 1967-68	4	M	D & P	4	0.80
Fletcher & Atkinson (1972)	California, 1969-70	1	L	D & P	22	0.81
Grocke (1982)	Australia, 1981	1-6	L	D & P	4	0.82
Haberman (1977)	Pennsylvania, 1974	4-6	M	D & P	8	0.57
Israel (1968)	New York, 1967-68	1,2	L	Tutorial	36	0.16
Litman (1977)	Illinois, 1972-73	4-6	L	D & P	36	0.23
MacLean (1974)	Pennsylvania, 1970-71	3-5	M	Tutorial	3	0.62
Mendelsohn (1972)	New York, 1968-69	2-6	M	D & P	20	0.49
Morgan, Sangston & Pokras (1977)	Maryland, 1975-76	3-6	M	D & P	60	0.23

Table 2 (continued)

Study	Place & Time	Grade	Course Content	Use	Weeks of Instruction	Achievement ES
Nabors (1974)	Missouri, 1973	5.6	S	Management	36	0.36
Palmer (1973)	California, 1972-73	4-6	M	D & P	16	0.36
Prince (1969)	Mississippi, 1967-68	1-6	M	D & P	36	0.64
Ragosta (1983)	California, 1977-81	1-6	C	D & P	108	0.30
Roberts (1982)	Utah, 1977-81	3-6	L	Management	108	0.02
Suppes & Morningstar (1969)	California, 1966-68	1-6	M	D & P	22	0.28
Thompson (1972)	Texas, 1970-71	4-6	L	D & P	36	0.11
Warner (1979)	Ohio, 1978-79	6	M	Tutorial	36	1.31
Wilson & Fitzgibbon (1970)	Michigan, 1969-70	4,5	L	D & P	16	0.40

Note. M = mathematics; L = language arts; S = science; D & P = drill and practice.

[a]This study yielded a statistically significant effect, but the report did not include enough detail for direct calculation of ES. The ES reported here and used in the analysis is an estimated value; it is the median ES in all studies of CBE that reported a statistically significant effect.

Table 3

Means and Standard Errors of Effect Sizes

For 25 CAI Studies Classified by Study Features

Categories	N	Effect Size	
		M	SE
Use of computer			
Drill and Practice	21	0.45	0.06
Tutorial	4	0.64	0.28
Author of program			
Local	10	0.45	0.08
Other	15	0.50	0.09
CCC material			
Yes	12	0.48	0.08
No	13	0.48	0.10
Duration of instruction			
One semester or less	11	0.47	0.08
One semester-one year	12	0.52	0.11
More than one year	2	0.26	0.05
Subject assignment			
Random	5	0.57	0.24
Nonrandom	20	0.46	0.06
Instructors			
Same	7	0.44	0.09
Different	18	0.49	0.08
Time-on-task			
Experimental > Control	15	0.44	0.08
Experimental = Control	10	0.53	0.10
Test author bias			
Commercial test	19	0.47	0.08
Local test	6	0.52	0.12
Evaluator involvement			
Involved	19	0.52	0.06
Not involved	6	0.36	0.17
Field-tested material			
Yes	17	0.49	0.08
No	8	0.45	0.10

Table 3 (continued)

Categories	N	Effect Size	
		M	SE
Class level			
Primary (1-3)	4	0.63	0.23
Primary & Middle (1-6)	9	0.43	0.08
Middle (4-6)	12	0.46	0.10
Course content			
Mathematics	15	0.56	0.08
Language/Reading	7	0.43	0.12
Combined	3	0.17	0.10
Ability of subjects			
Low	13	0.44	0.08
Average/Mixed	12	0.51	0.10
Nature of publication			
Unpublished	9	0.48	0.13
Dissertation	7	0.34	0.03
Published	9	0.59	0.09
Year of publication			
Before 1969	5	0.47	0.13
1970-1974	11	0.48	0.08
1975-1979	6	0.53	0.19
1980-1984	3	0.38	0.29

Table 4

Relationships of Time-on-Task Variables

To Achievement Effects in 25 CAI Studies

Variable	M	SD	r with ES
Sessions per week	4.08	1.63	0.10
Number of weeks	26.00	22.07	-0.17
Minutes per session	15.56	8.66	0.06
Total time-on-task in minutes	1564.50	2177.40	-0.10

Table 5

Effects Sizes for Subgroups and Subtests within Studies

Study	Ability		Content		Grades	
	Low	High	Language	Mathematics	Primary	Middle
Chiang, Stauffer, & Cannara (1978)			0.24	0.14		
Davies (1972)					0.18	0.39
Dunn, Morgan, & Richardson--Study I	0.55	0.35				
Durward (1973)	0.54	0.08				
Easterling (1982)			0.01	0.02		
Mendelsohn (1972)					0.62	0.40
Morgan, Sangston, & Pokras (1977)	0.23	0.13			0.17	0.24
Prince (1969)	0.89	-0.32			0.87	0.44
Ragosta (1983)			0.10	0.49	0.35	0.25
Suppes & Morningstar (1969)					0.40	0.16